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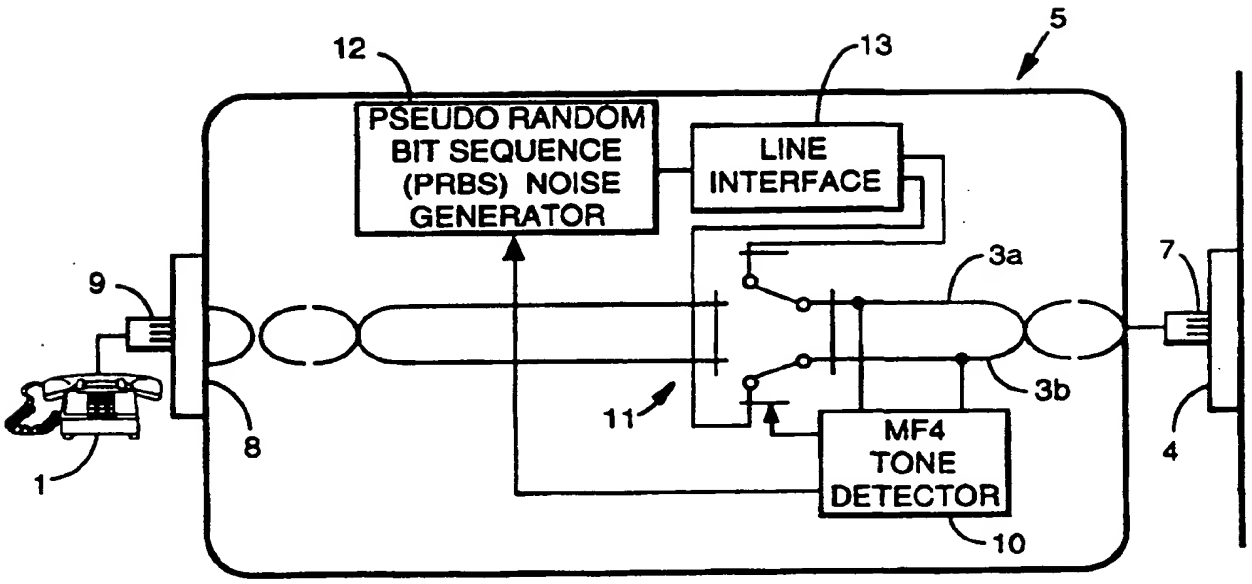

(57) Abstract

Apparatus is disclosed for testing a telephone line between a customer's network termination equipment and an exchange associated therewith. The apparatus comprises a field unit (5) positionable between the customer's telephone (1) and the network termination equipment (4), and an exchange unit (16) positionable at the exchange (2). The exchange unit (6) comprises activating means (16) for initiating a test sequence, and processing means (14) for controlling testing and analysing test results. The field unit (5) comprises a noise generator (12) for sending noise signals to the exchange unit (6), and a sensor (10) for activating the noise generator upon receipt of the activating signal. The processing means (14) analyses the incoming noise signal to provide a measure of the line attenuation.

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CUSTOMER LINE TESTER

This invention relates to apparatus for, and a method of, measuring the transmission characteristics of a telephone line connecting a customer's telephone apparatus to a local exchange. The invention is particularly concerned with the measurement of the transmission characteristics of a telephone line constituted by a copper pair.

Until recently, it was believed that copper pair telephone lines were incapable of carrying high bandwidth surfaces such as Video on Demand (VoD), home shopping and other interactive and multimedia services. Indeed, in the past, copper pair telephone wires have not had to carry large quantities of information, as the bandwidth required to carry human voices is only about 4kHz. If attempts are made to transmit signals with higher frequencies, problems arise through attenuation of the signal strength, attenuation increasing with increasing frequency. The recent introduction of asymmetric digital subscriber line (ADSL) technology does, however, enable the existing copper access network to provide broadband services. ADSL operates on a single unconditioned copper pair telephone line, and provides a digital transmission path with a much higher data rate from the exchange to the customer than in the reverse direction. ADSL technology enables a data rate of about 2Mbit/s to be carried for distances up to about 3 miles. Beyond this, the attenuation of a copper pair telephone line prevents satisfactory transmission of such a high bandwidth signal. In the United Kingdom, about 90% of telephony customers are within 3 miles of their local exchange. In principle, therefore, all such customers can receive ADSL signals over the existing copper pair local access network.

Of course, the actual distance over which ADSL signals can be transmitted will depend on the actual state of the line concerned. Before offering a customer high bandwidth services such as the VoD, therefore, it is important for the service provider to know whether that customer's line is capable of carrying the service.

The present invention provides apparatus for testing a telephone line between a customer's network termination equipment and an exchange associated therewith, the apparatus comprising a field unit positionable between the

customer's telephone and the network termination equipment, and an exchange unit positionable at the exchange, the exchange unit comprising activating means for sending an activating signal to the field unit, and processing means for controlling testing and analysing test results, and the field unit comprising a noise generator for sending noise signals to the exchange unit, and a sensor for activating the noise generator upon receipt of the activating signal, wherein the processing means comprises analysis means for analysing the incoming noise signal and providing a measure of the line attenuation.

Advantageously, the field unit further comprises a switch for connecting the line to the telephone or to the noise generator.

In a preferred embodiment, the noise generator is a PRBS generator, preferably one that generates a signal whose sequence length is 255 bits at a bit rate of 3.5Mbit/s. In this case, the noise generator generates a comb of frequencies spaced at 14kHz intervals, and so provides a large number of possible test frequencies.

The activating means may be constituted by an MF generator. In this case, the sensor is constituted by an MF tone detector connected across the telephone line. Alternatively, both the activating means and the sensor may be constituted by V.23 FSK modems.

Preferably, the processing means is constituted by a PC-based controller and a data acquisition card

In a preferred embodiment, the processing means further comprises means for comparing the measured line attenuation with a predetermined threshold, and the exchange unit further comprises indicator means for indicating whether the measured line attenuation exceeds the predetermined threshold.

Advantageously, the exchange unit further comprises means for monitoring noise on the line in the absence of noise signals originating from the noise generator. Preferably, the monitoring means comprises means for measuring voltage on the line, and means for converting the measured voltage to a measure of the power carried by the line, and wherein the analysis means analyses the power measure to provide a measure of the noise on the line. In this case, the processing means may further comprise means for varying the predetermined threshold in dependence upon the value of the measured noise.

The invention also provides a method of testing a telephone line between a customer's network termination equipment and an exchange associated therewith, the method comprising the steps of transmitting an activating signal down the line from an exchange unit at the exchange to a field unit positioned between the customer's telephone and the network termination equipment, detecting the activating signal at the field unit, transmitting a noise signal from the field unit to the exchange unit, and analysing the noise signal at the exchange unit to provide a measure of the line attenuation.

Advantageously, the method further comprises the step of disconnecting the customer's telephone from the line when the field unit detects the activating signal prior to the noise signal being generated by the field unit.

In a preferred embodiment, the method further comprises the steps of comparing the measured line attenuation with a predetermined threshold, and indicating whether the measured line attenuation exceeds the predetermined threshold.

Advantageously, the method further comprises the step of monitoring noise on the line in the absence of noise signals originating from the field unit. Preferably, the monitoring step is such as to measure voltage on the line, and to convert the measured voltage to a measure of the power carried by the line, and wherein the analysis step is such as to analyse the power measure to provide a measure of the noise on the line. In this case, the method may further comprise the step of varying the predetermined threshold in dependence upon the value of the measured noise.

The invention further provides a field unit for use in testing a telephone line between a customer's network termination equipment and an exchange unit, the field unit comprising a noise generator for sending noise signals to the exchange unit, a sensor for activating the noise generator upon receipt of an activating signal from the exchange unit, and a switch for connecting the line to the noise generator and for disconnecting the customer's telephone apparatus from the line upon receipt of the activating signal by the sensor.

Advantageously, the field unit further comprises a plug for connecting the unit to the telephone socket of a customer's network termination equipment, and with a socket for connection of the plug of the customer's telephone apparatus.

The invention also provides an exchange unit for use in testing a telephone line between the exchange unit and a customer's network termination equipment, the exchange unit comprising activating means for initiating a test sequence, and processing means for controlling testing and analysing test results, wherein the processing means is arranged to analyse incoming noise signals to provide a measure of the attenuation of the telephone line.

A customer line tester constructed in accordance with the invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic representation of the tester;

Figure 2 is a schematic representation of a customer-end plug-in unit forming part of the tester; and

Figure 3 is a block circuit diagram of an exchange-end unit forming part of the tester.

Referring to the drawings, Figure 1 shows the customer line tester together with a customer's telephone apparatus 1, the local exchange 2 associated therewith and a copper pair line 3 connecting the telephone apparatus to the local exchange via a line jack socket (the customer's master socket) 4. The socket 4 constitutes network termination equipment. The tester is constituted by a customer-end plug-in unit 5 and an exchange-end unit 6. The plug-in unit 5 is positioned, in use, between the telephone apparatus 1 and the customer's master socket 4. Accordingly, the unit 5 is provided with a plug 7 for engagement with the customer's master socket 4, and with a socket 8 into which a plug 9 associated with the telephone apparatus 1 can be fitted.

As shown in Figure 2, the plug-in unit 5 includes a tone detector 10 which is connected across the two wires 3a and 3b of the line 3. The output of the tone detector 10 is connected to a switch 11 which can be used to connect the output of a pseudo-random bit sequence (PRBS) noise generator 12 to the line via a line interface 13.

As shown in Figure 3, the exchange-end unit 6 includes a PC-based controller 14, a data acquisition card 15, an MF generator 16 and a line interface/switch 17. The line interface 17 connects the telephone line 3a, 3b to

vary the predetermined threshold referred to above. Thus, where the line 3 is inherently noisy, the predetermined threshold used to evaluate the lines suitability for ADSL should be varied depending upon the noise margin in the system. Thus, the predetermined threshold will be reduced for noisy lines. In this way, a more accurate evaluation of a line's suitability for ADSL can be carried out, as the predetermined threshold can be evaluated for each line (as opposed to the predetermined threshold having a large safety measure the cover the maximum noise level expected).

It will be apparent that the test system described above could be modified in a number of ways. For example, the components of the plug-in unit 5 could be incorporated into the master socket (network termination equipment) 4. Indeed, as master sockets are up-graded to give greater functionality, it is probable that this will be the preferred way of providing the test unit at the customer end. The technical characteristics of such a network termination equipment are described in the specification of our co-pending International patent application GB95/..... (Applicant's reference A24854 - claiming priority from patent applications GB9409842.3, GB9416597.4 and EP94307186.0). For the time being, however, the use of a plug-in unit is desirable, as this can be sent to a customer requesting a particular service, the unit can be plugged-in, the test carried out, and the unit returned to the service provider for use elsewhere. It would also be possible to replace the MF generator by a V.23 FSK modem, in which case the tone detector 10 would also be a V.23 FSK modem.

An important advantage of the system described above is the ability to link deployment decisions to a central location such as a local exchange or, more preferably, a central office.

CLAIMS

1. Apparatus for testing a telephone line between a customer's network termination equipment and an exchange associated therewith, the apparatus comprising a field unit positionable between the customer's telephone and the network termination equipment, and an exchange unit positionable at the exchange, the exchange unit comprising activating means for sending an activating signal to the field unit, and processing means for controlling testing and analysing test results, and the field unit comprising a noise generator for sending noise signals to the exchange unit, and a sensor for activating the noise generator upon receipt of the activating signal, wherein the processing means comprises analysis means for analysing the incoming noise signal and providing a measure of the line attenuation.

2. Apparatus as claimed in claim 1, wherein the field unit further comprises a switch for connecting the line to the telephone or to the noise generator.

3. Apparatus as claimed in claim 1 or claim 2, wherein the noise generator is a PRBS generator.

4. Apparatus as claimed in claim 3, wherein the PRBS generator generates a signal whose sequence length is 255 bits at a bit rate of 3.5Mbit/s.

5. Apparatus as claimed in any one of claims 1 to 4, wherein the activating means is constituted by an MF generator.

6. Apparatus as claimed in claim 5, wherein the sensor is constituted by an MF tone detector connected across the telephone line.

7. Apparatus as claimed in any one of claims 1 to 4, wherein the activating means is constituted by a V.23 FSK modem.

8. Apparatus as claimed in claim 7, wherein the sensor is constituted by a V.23 FSK modem.

9. Apparatus as claimed in any one of claims 1 to 8, wherein the processing means is constituted by a PC-based controller and a data acquisition card.

10. Apparatus as claimed in any one of claims 1 to 9, wherein the processing means further comprises means for comparing the measured line attenuation with a predetermined threshold, and the exchange unit further comprises indicator means for indicating whether the measured line attenuation exceeds the predetermined threshold.

11. Apparatus as claimed in any one of claims 1 to 10, wherein the exchange unit further comprises means for monitoring noise on the line in the absence of noise signals originating from the noise generator.

12. Apparatus as claimed in claim 11 when appendent to claim 10, wherein the monitoring means comprises means for measuring voltage on the line, and means for converting the measured voltage to a measure of the power carried by the line, and wherein the analysis means analyses the power measure to provide a measure of the noise on the line.

13. Apparatus as claimed in claim 12, wherein the processing means further comprises means for varying the predetermined threshold in dependence upon the value of the measured noise.

14. A method of testing a telephone line between a customer's network termination equipment and an exchange associated therewith, the method comprising the steps of transmitting an activating signal down the line from an exchange unit at the exchange to a field unit positioned between the customer's telephone and the network termination equipment, detecting the activating signal at the field unit, transmitting a noise signal from the field unit to the exchange unit,

and analysing the noise signal at the exchange unit to provide a measure of the line attenuation.

15. A method as claimed in claim 14, wherein the noise signal has a sequence length of 255 bits at a bit rate of 3.5Mbit/s.

16. A method as claimed in claim 14 or claim 15, further comprising the step of disconnecting the customer's telephone from the line when the field unit detects the activating signal prior to the noise signal being generated by the field unit.

17. A method as claimed in any one of claims 14 to 16, further comprising the steps of comparing the measured line attenuation with a predetermined threshold, and indicating whether the measured line attenuation exceeds the predetermined threshold.

18. A method as claimed in any one of claims 14 to 17, further comprising the step of monitoring noise on the line in the absence of noise signals originating from the field unit.

19. A method as claimed in claim 18 when appendent to claim 17, wherein the monitoring step is such as to measure voltage on the line, and to convert the measured voltage to a measure of the power carried by the line, and wherein the analysis step in such as to analyse the power measure to provide a measure of the noise on the line.

20. A method as claimed in claim 19, further comprising the step of varying the predetermined threshold in dependence upon the value of the measured noise.

21. A field unit for use in testing a telephone line between a customer's network termination equipment and an exchange unit, the field unit comprising a noise generator for sending noise signals to the exchange unit, a sensor for activating the noise generator upon receipt of an activating signal from the exchange unit, and a switch for connecting the line to the noise generator and for

disconnecting the customer's telephone apparatus from the line upon receipt of the activating signal by the sensor.

22. A field unit as claimed in claim 21, where the noise generator is a PRBS generator which generates a noise signal having a sequence length of 255 bits at a bit rate of 3.5Mbit/s.

23. A field unit as claimed in claim 21 or claim 22, further comprising a plug for connecting the unit to the telephone socket of a customer's network termination equipment, and with a socket for connection of the plug of the customer's telephone apparatus.

24. An exchange unit for use in testing a telephone line between the exchange unit and a customer's network termination equipment, the exchange unit comprising activating means for initiating a test sequence, and processing means for controlling testing and analysing test results, wherein the processing means is arranged to analyse incoming noise signals to provide a measure of the attenuation of the telephone line.

Fig.1.

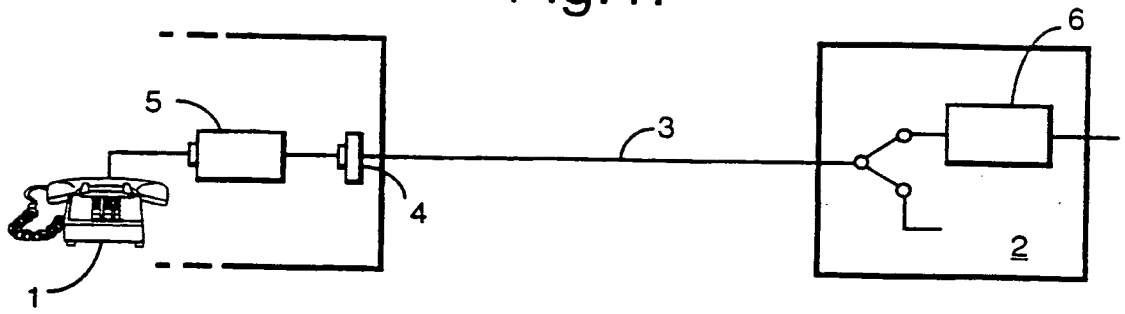


Fig.2.

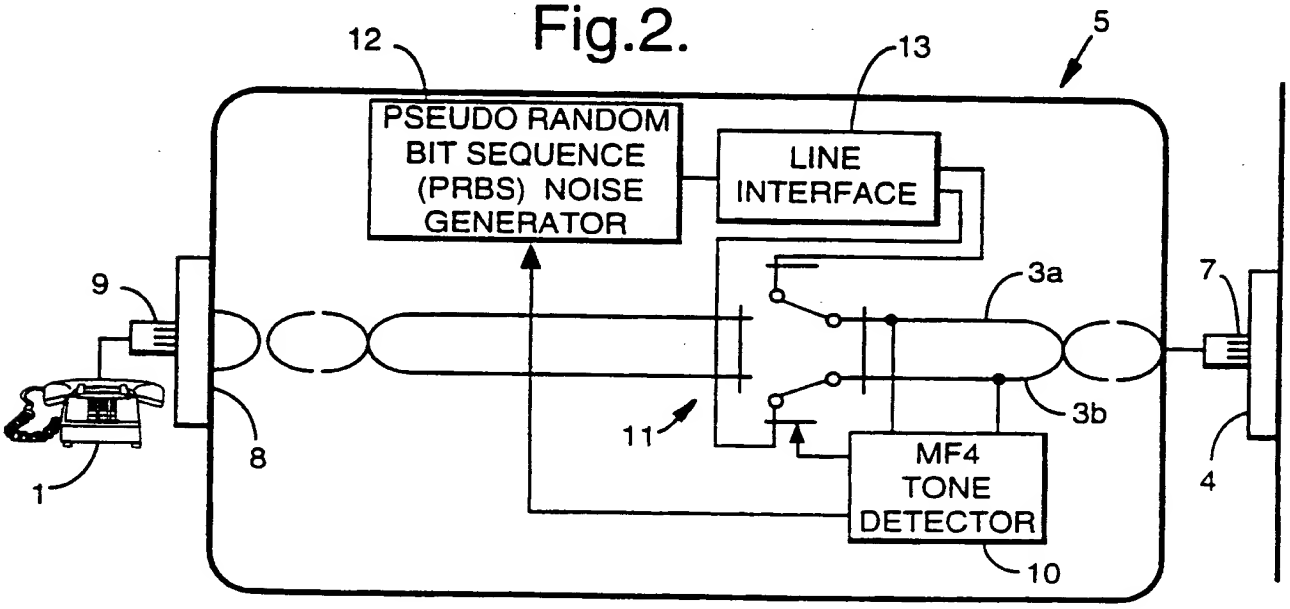
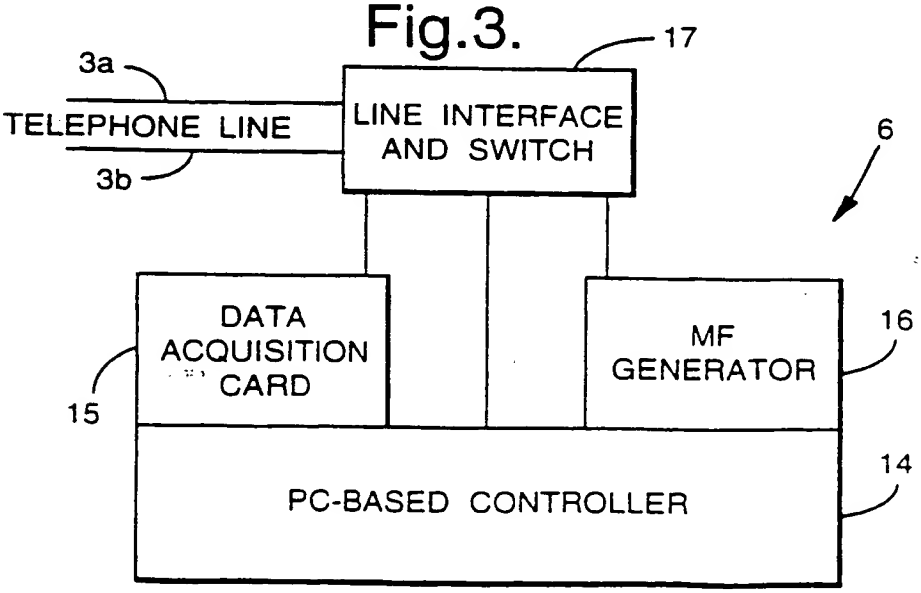


Fig.3.



INTERNATIONAL SEARCH REPORT

Internat'l Application No
PCT/GB 95/01099

A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04M G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 81 (E-1321) 18 February 1993 & JP,A,04 277 964 (FUJITSU) 2 October 1992 see abstract ---	1,14,21, 24
A	TELEKTRONIKK, vol.81, no.1, 1985, NO pages 129 - 134 P.KLEPSLAND 'Evaluating the Quality of Twisted Pair Cables in the Subscriber Network' see abstract; figure 1 ---	1,14,21, 24
A	DE,C,37 23 115 (TELENORMA) 16 March 1989 see abstract; figure see column 2, line 15 - column 3, line 32 see column 4, line 64 - column 5, line 4 --- -/--	1,14,21, 24

[X] Further documents are listed in the continuation of box C.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	NTZ NACHRICHTENTECHNISCHE ZEITSCHRIFT, vol.47, no.1, January 1994, BERLIN DE pages 12 - 15 H.W.ARWEILER ET AL. 'Schnelles Messverfahren zur Bestimmung der ISDN-Leitungsparameter' see the whole document ---	1,14,21, 24
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A	EP,A,0 572 117 (AT&T) 1 December 1993 see abstract; figures 1,2 ---	1,14,21, 24
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 248 (E-431) 26 August 1986 & JP,A,61 077 460 (FUJITSU) 21 April 1986 see abstract -----	1,14,21, 24

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the exchange unit 6. The PC controller 14 operates at 20M samples/sec and at a 12-bit resolution.

In use, when it is desired to test the line 3, for example to ascertain whether the line will support ADSL, the plug-in unit 5 is positioned between the customer's telephone 1 and the associated master socket 4. The MF generator 16 in the exchange unit 6 is triggered to transmit an MF signal along the line 3a, 3b via the line interface 17. Alternatively, the MF generator 16 could be triggered to send a CLASS type signal. This signal travels along the line 3a, 3b, and is received by the tone detector 10 in the plug-in unit 5. The tone detector 10 controls the switch 11 to disconnect the telephone 1 and to connect the PRBS generator 12 to the line 3a, 3b via the line interface 13. The PRBS generator 12 generates a signal whose sequence length is 255 bits at a bit rate of 3.5Mbit/s. This results in a series of spectral lines (a comb of frequencies) spaced at 14kHz intervals. The test signal is sent along the line 3a, 3b to the exchange unit 5.

The PC-based controller 14 of the exchange unit 5 is provided with suitable software for processing the captured signal. The first processing step carried out is to analyse the incoming analogue signal, digitise it and place it in a file in the data acquisition card 15. The controller 14 then analyses the content of the file using an algorithm which employs a Fourier transform to convert the time domain data into frequency domain data. This allows measurement of the received power level at a range of frequencies. These power levels are then compared with those of the original signal to give a measure of the line attenuation. The line attenuation is then compared with a predetermined threshold to evaluate the line's suitability for ADSL. For example, the predetermined threshold may lie within the range of 50dB to 60dB at 300kHz. The exchange unit 5 may be configured so that the output is a simple decision as to whether or not the line 3 is suitable for ADSL. For example, a "traffic lights" approach could be used - a green light indicating suitability, a red light indicating unsuitability, and an amber light representing a region of uncertainty due to measurement inaccuracy and noise margins.

Although the PRBS generator 12 is arranged to send a comb of frequencies along the line 3a, 3b for test purposes, it would be possible to use a single frequency. Thus, in practice, the exchange unit 6 carries out its analysis at

only one frequency (300kHz for ADSL testing). One reason for using the comb of frequencies is that interference is possible at the preferred frequency, in which case the exchange unit 6 will be instructed to take a measurement at a different frequency. In some cases, it would be preferable to analyse measurements taken at a range of frequencies, thereby improving the accuracy of line assessment.

Moreover, by using a comb of frequencies, the same plug-in unit 5 can be used to test a line to check its suitability for carrying other high bandwidth services. For example, if it is required to test a line to check its suitability of carrying very high speed ADSL (VADSL), the PRBS generator 12 would generate a signal whose sequence length is 255 bits at a bit rate of 30 Mbit/s. The system could also be used to assess a line's suitability for carrying basic rate ISDN (BR-ISDN). Thus, the system could be operated at a variety of bit rates and sequence lengths, thereby permitting testing for different services. Moreover, depending on the service which is desired to be carried, the software in the exchange unit 5 will arrange for measurement of the received power level at the best frequency for the particular service required. In other words, because the PRBS generator generates a comb of frequencies, it is necessary to provide only a single plug-in unit 5 for testing lines for many different purposes, and this obviously leads to manufacturing and stocking cost reductions.

The exchange unit 5 can also be used to measure noise on the line 3 when the PRBS generator 12 is turned off, that is to say the exchange unit can be used to monitor noise levels on the line in the absence of the test signal. In this case, the exchange unit 5 measures the voltage on the line, and converts this to a measurement of the power carried by the line, this power being proportional to the noise. Here again, the controller 14 analyses the power data stored in the card 15, using a suitable algorithm, to provide a measure of the noise. There are two types of noise to be considered here, namely non-impulsive noise (which may result, for example, from interactions with a nearby radio generator) and impulsive noise (which may be caused by switching transients). Impulsive noise, due to its time-varying nature, is difficult to characterise without monitoring the line for an extended period, and this is not practicable with the test system of the present invention. Non-impulsive noise can, however, be measured in the manner described above. Once this noise measurement has been made, it can be used to

INTERNATIONAL SEARCH REPORT

mation on patent family members

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